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(58) Field of search
E2A

(54) Locking Devices

(57) A keyhole-less electronic padlock uses inductive coupling from a key to a lock to transmit a multibit lock code from the key to the lock to release the lock. The lock and key are reprogrammable to a different lock code by a programming unit which generates a new lock code by combining the old lock code with a random number. The lock circuitry provides a delay of e.g. one second after unsuccessfully operating with one lock code before it will process another to make it impracticable to attempt to break the lock code by a purely random method. The key circuitry is automatically switched on by a reed switch in the key which is closed by a magnet element on the lock when the two are brought together, to conserve battery power.

The mechanical locking structure may include a rod 169 which can move into engagement with the end of the hasp, and two retaining springs locatable symmetrically on opposed sides of the rod in a recess on the rod, to resist opening of the lock by gross mechanical shock.

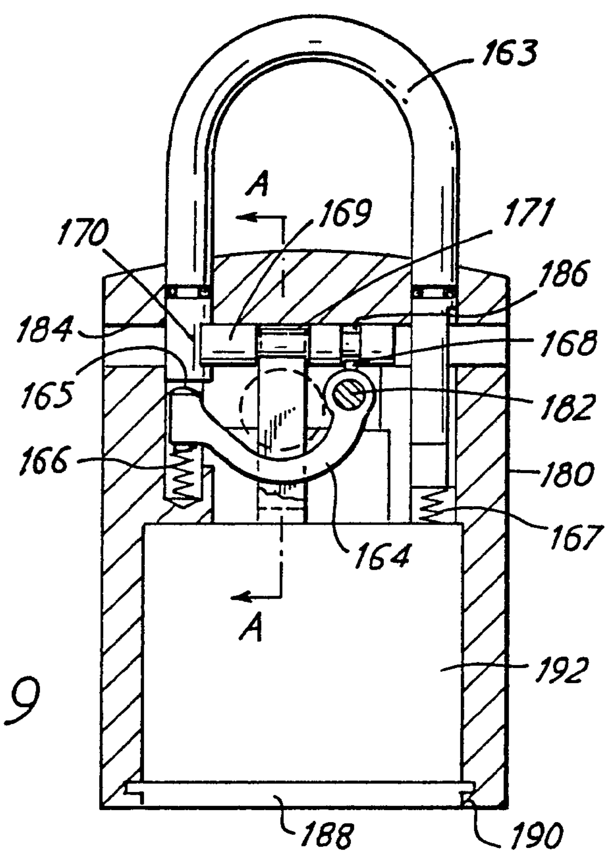

FIG. 9

Continued overleaf . . .

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

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The lock is released by solenoids moving the springs apart. If a two-part lock casing is employed, the two parts may be held together by a bolt which is accessible only through the aperture which receives the free end of the hasp, so that the casing can only be disassembled when the lock is open.

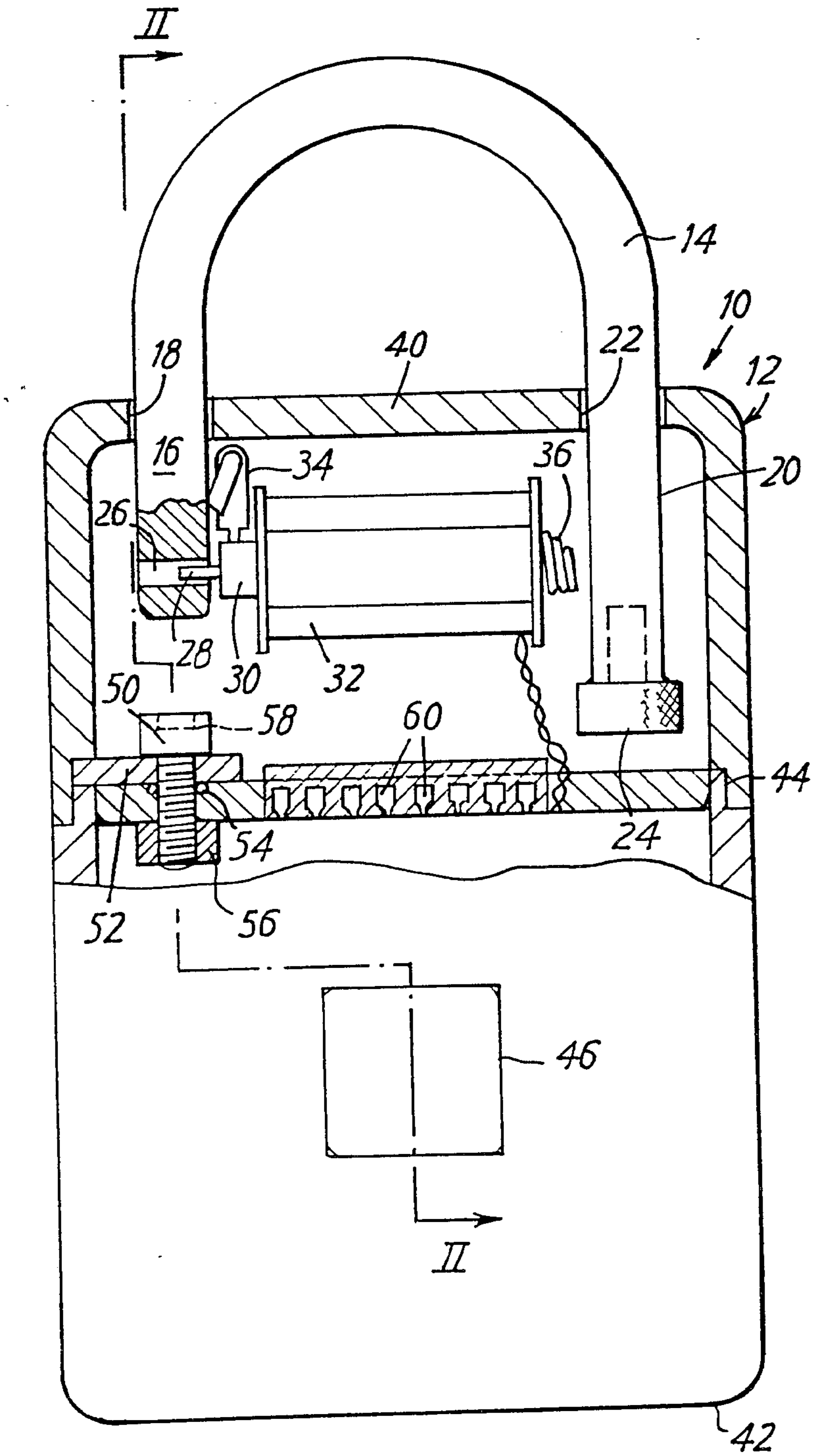

II
14
10
40
22
12
18
16
34
36
20
26
28
30
32
50
58
60
44
54
24
52
56
46
II
42

FIG. 1

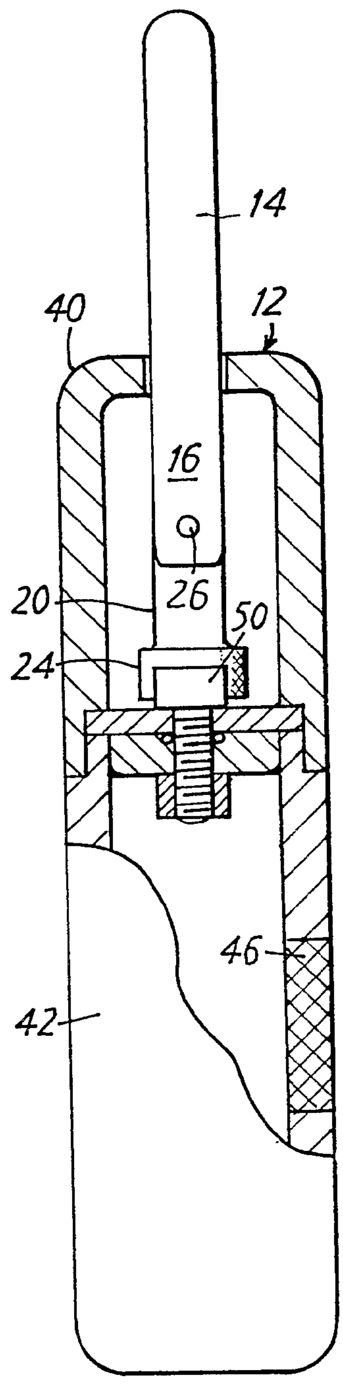

14
40
12
16
26
20
50
24
46
42

FIG.2

2144433

2/7

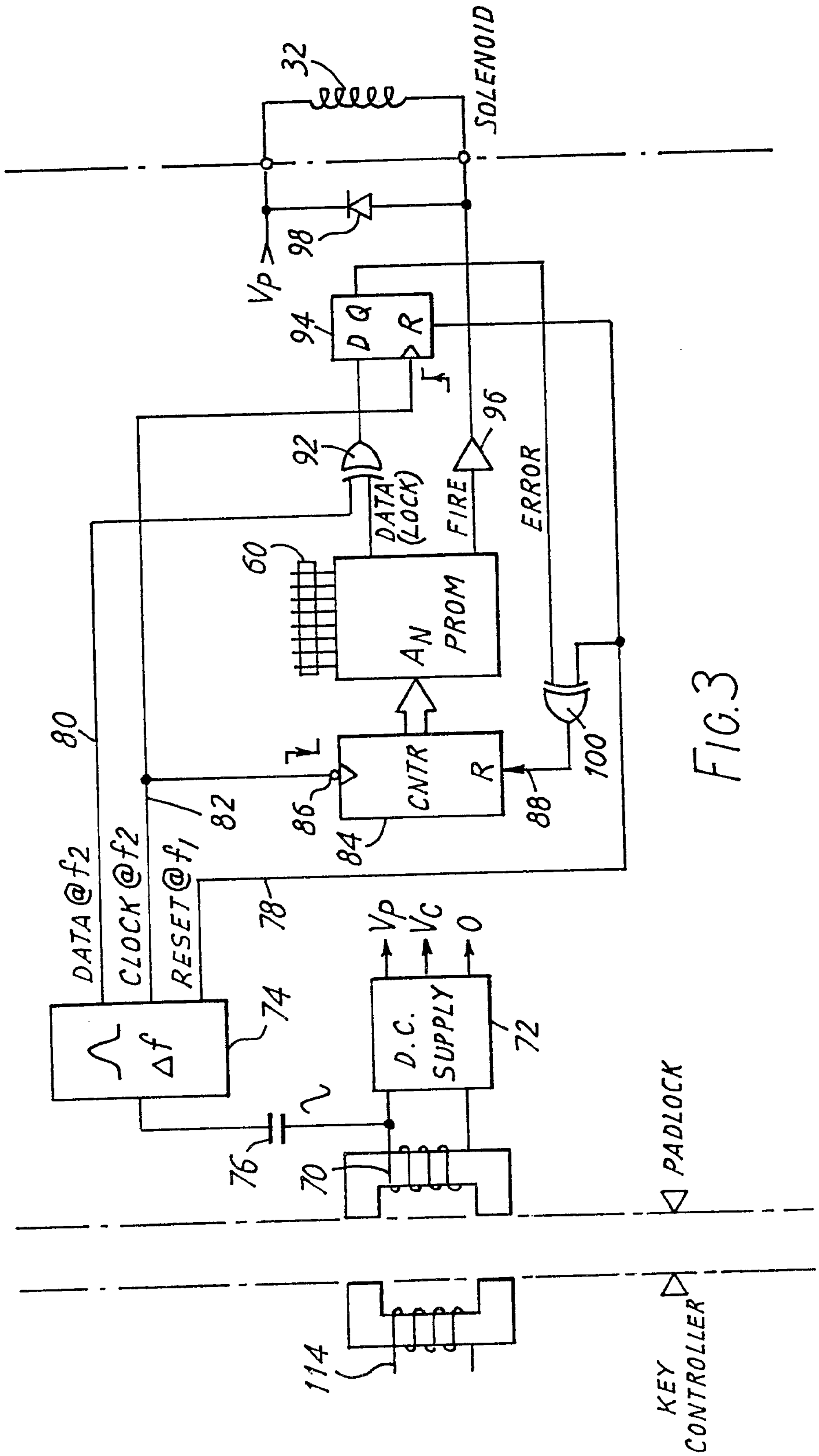


FIG.3

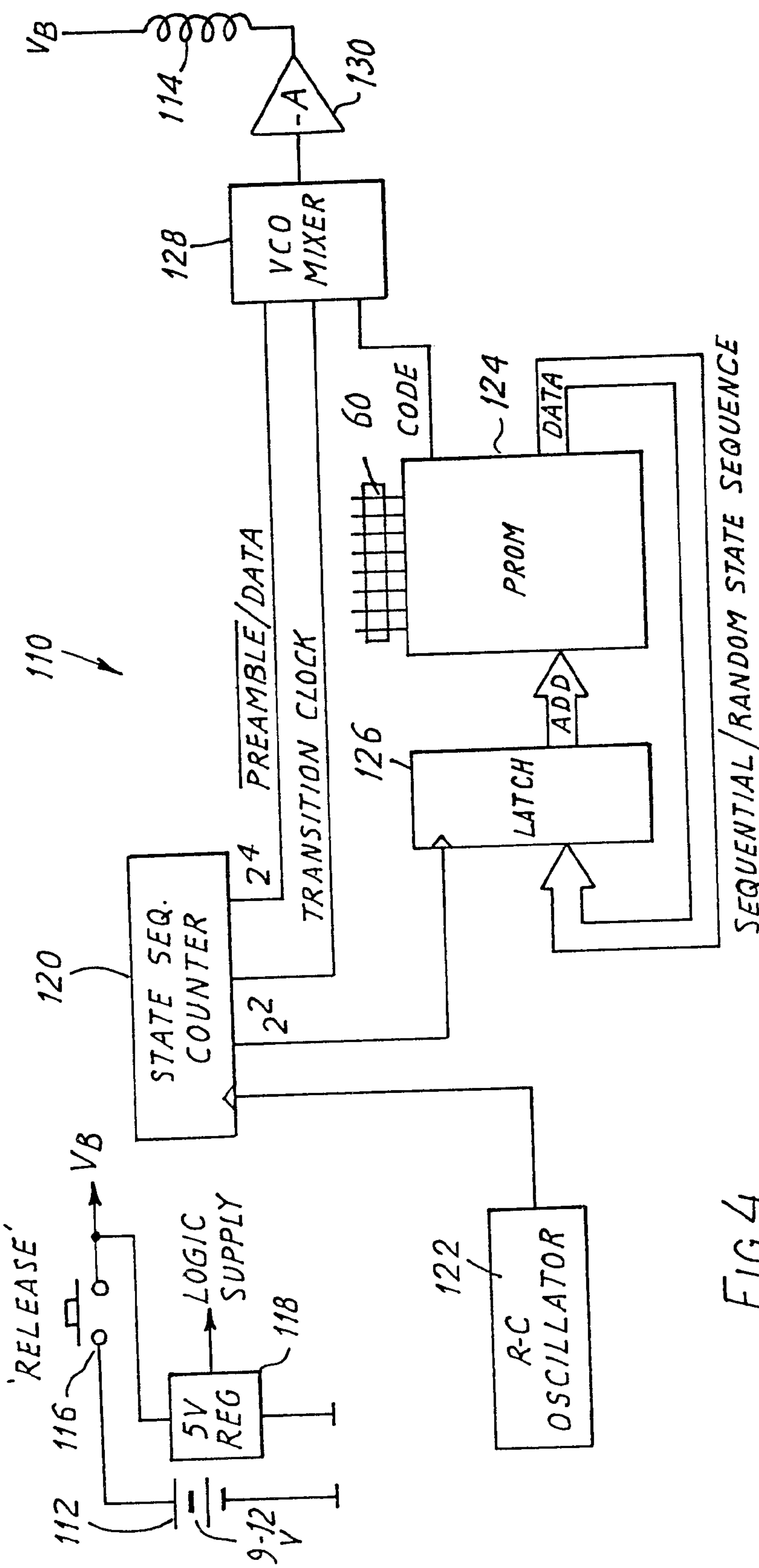

VB
114
-A
130
128
VCO MIXER
110
PREAMBLE/DATA
TRANSITION CLOCK
60
CODE
124
DATA
PROM
126
ADD
LATCH
SEQUENTIAL/RANDOM STATE SEQUENCE
120
STATE SEQ. COUNTER
2^4
2^2
'RELEASE'
VB
LOGIC SUPPLY
116
118
5V REG
122
R-C OSCILLATOR
112
9-12 V

FIG. 4

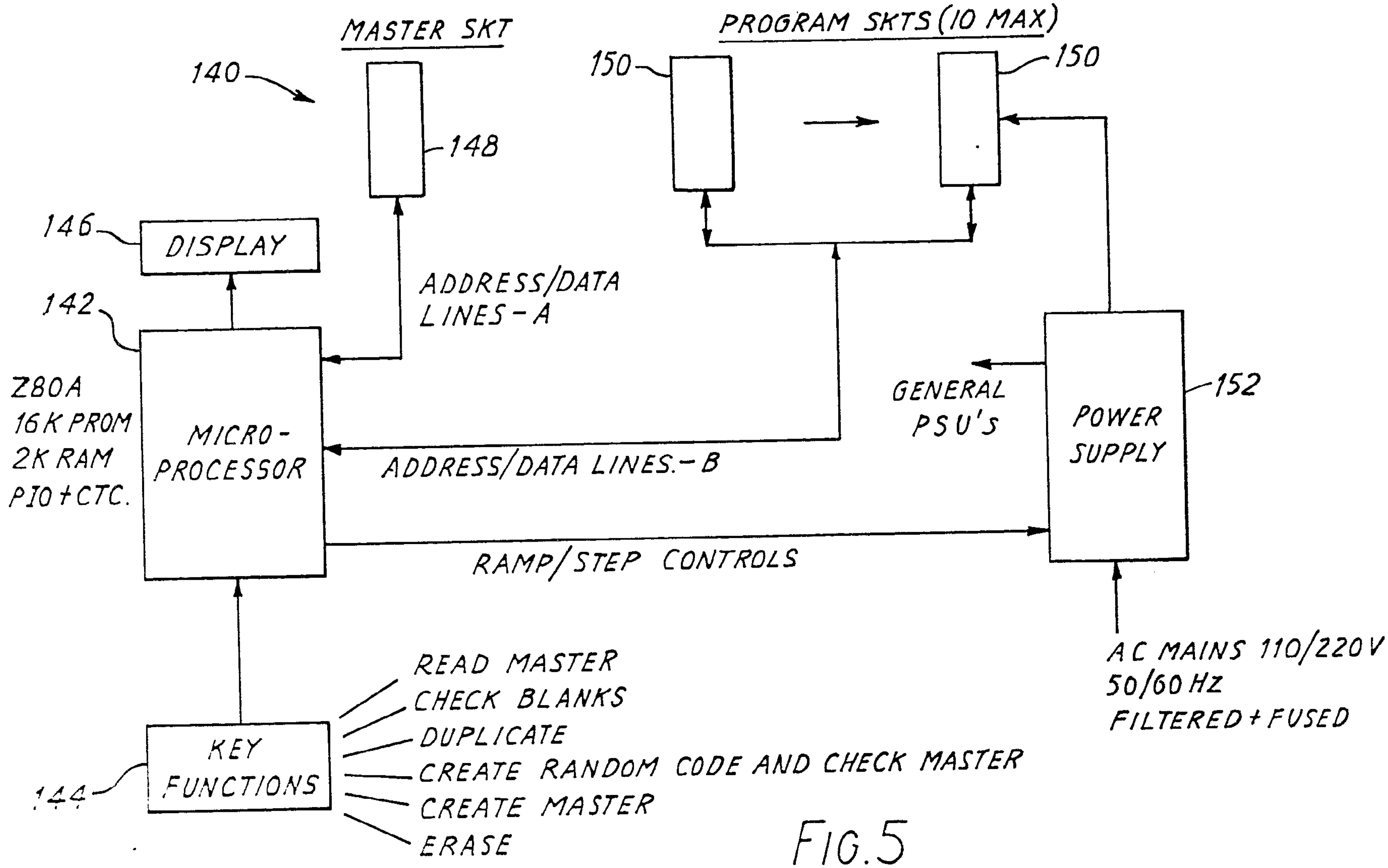

MASTER SKT
PROGRAM SKTS (10 MAX)
140
148
150
150
146
DISPLAY
142
ADDRESS/DATA
LINES-A
Z80A
16K PROM
2K RAM
PIO+CTC.
MICRO-
PROCESSOR
ADDRESS/DATA LINES:-B
GENERAL
PSU'S
POWER
SUPPLY
152
RAMP/STEP CONTROLS
READ MASTER
CHECK BLANKS
DUPLICATE
CREATE RANDOM CODE AND CHECK MASTER
CREATE MASTER
ERASE
KEY
FUNCTIONS
144
AC MAINS 110/220V
50/60 Hz
FILTERED+FUSED

FIG.5

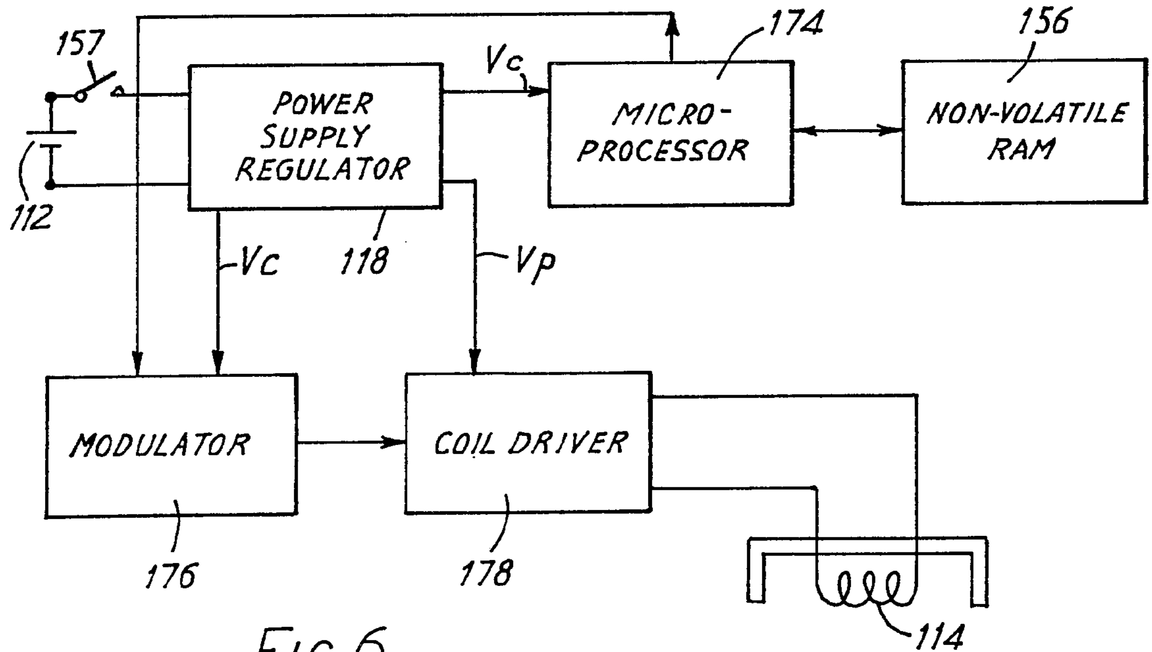

157
112
POWER SUPPLY REGULATOR
118
Vc
Vc
Vp
MICRO-PROCESSOR
174
NON-VOLATILE RAM
156
MODULATOR
176
COIL DRIVER
178
114

FIG.6

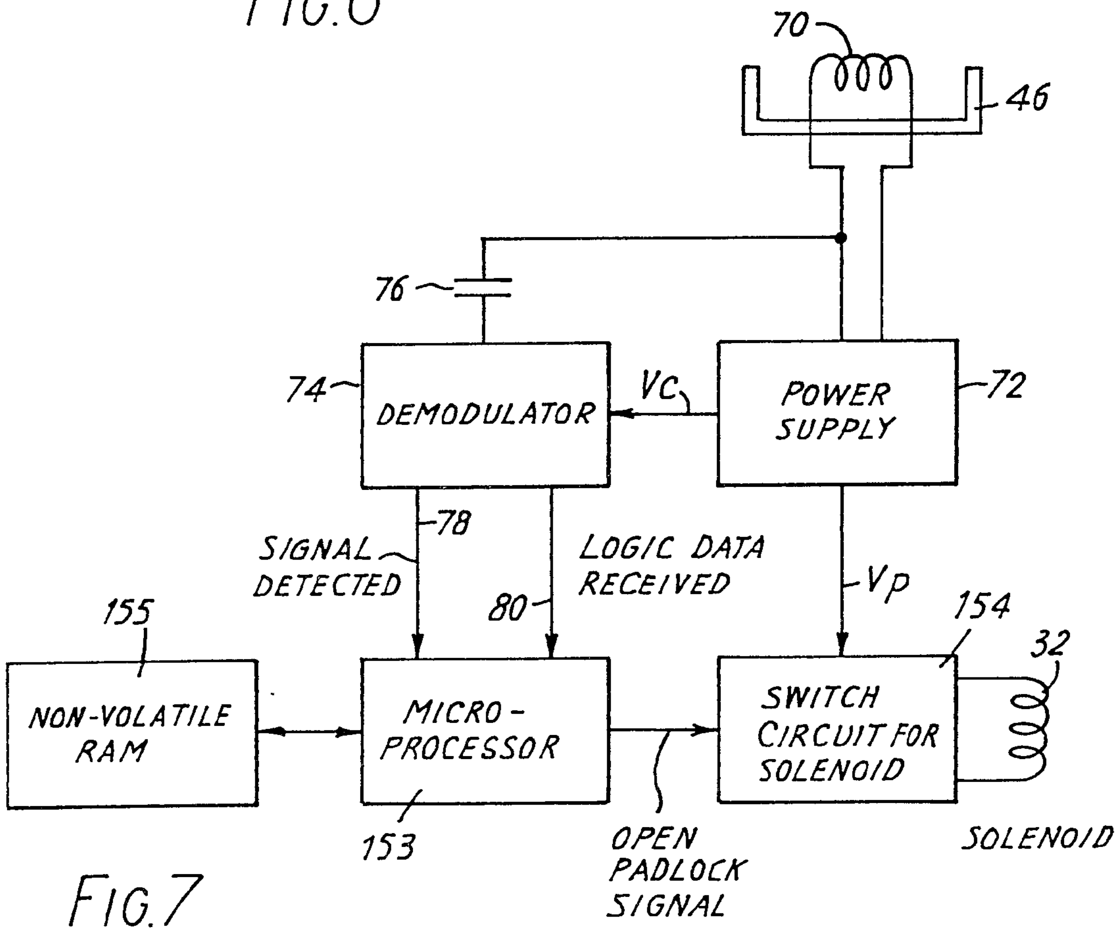

70
46
76
74
DEMODULATOR
Vc
POWER SUPPLY
72
78
SIGNAL DETECTED
LOGIC DATA RECEIVED
80
Vp
154
32
155
NON-VOLATILE RAM
MICRO-PROCESSOR
153
SWITCH CIRCUIT FOR SOLENOID
OPEN PADLOCK SIGNAL
SOLENOID

FIG.7

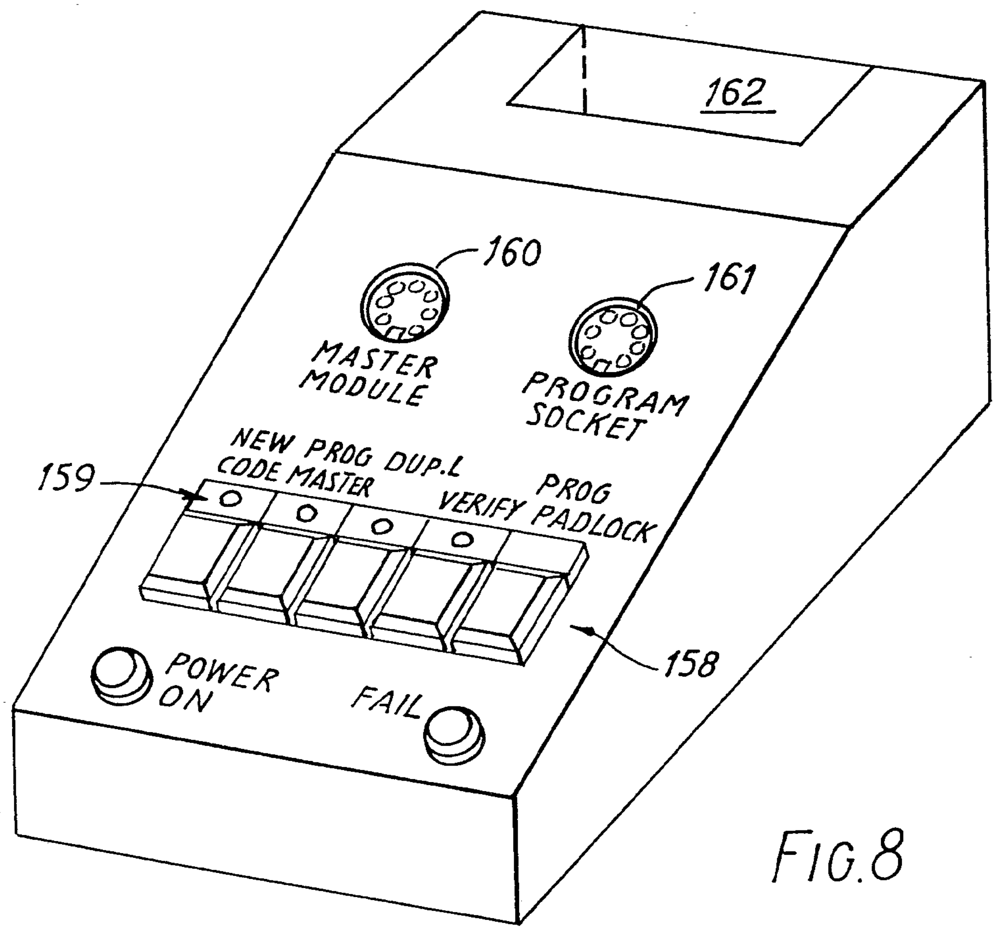
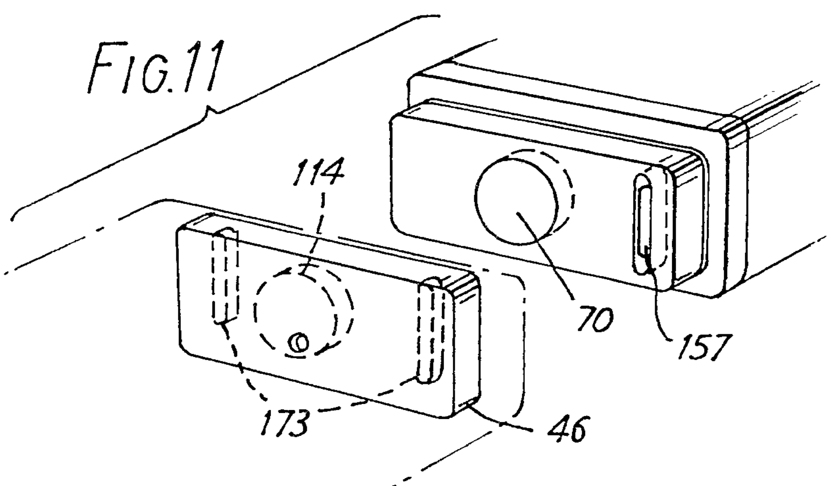

162
160
161
MASTER
MODULE
PROGRAM
SOCKET
NEW
CODE
PROG
MASTER
DUP.L
VERIFY
PROG
PADLOCK
159
158
POWER
ON
FAIL

FIG.8

FIG.11


114
70
157
173
46

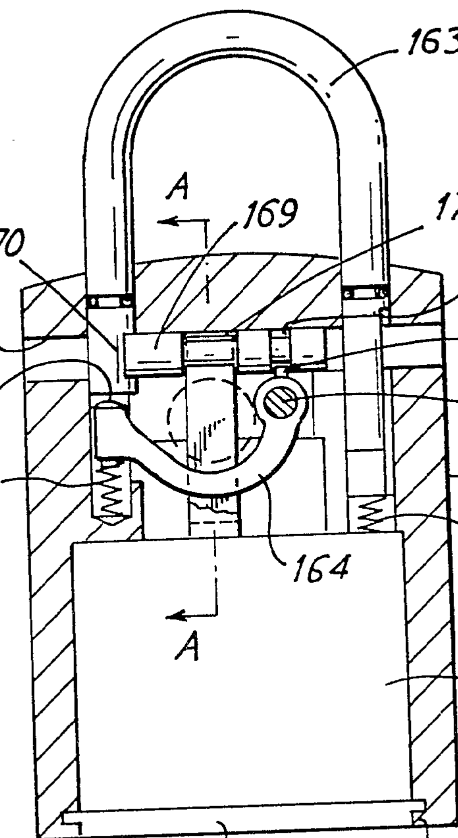

163
A
169
171
170
186
184
168
165
182
166
180
167
164
A
192
188
190

FIG.9

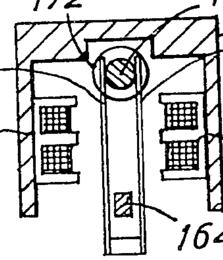

172
169
179
171
171
32
32
164

FIG.10

SPECIFICATION

Locking devices

This invention relates to locking devices and in particular to a keyhole-less electronic locking device.

British Patent 1,531,951 describes a keyhole-less electronic lock in which the key takes the form of an electronic pulse generating circuit coupled to an inductor. The lock has a corresponding inductor which can be inductively coupled to the inductor in the key unit and includes circuitry to identify a predetermined pulse pattern from the key unit. This fixed pulse pattern is set in the lock and in the key unit by a plug-in circuit carrying the pulse pattern on a dialable switch unit which can readily be reset. When the lock senses the appropriate pulse pattern from the key unit, a motor in the lock is driven to move a lock lug and hence release the lock.

There are situations where it is desired to provide the locking device in the form of a padlock, as this is a particularly convenient form of lock for use on the loading doors of warehouses and commercial vehicles for example. The device should be secure, and should allow for the possibility of a key unit being lost or stolen. Furthermore, the locks should be robust and able to withstand a certain amount of vibration and abuse.

It has been suggested, see U.K. Patent Application 2,055,951A at page 3 lines 97 to 101, to use an electronic system in a padlock. That proposal however involves the use of a barrel lock with an adapted key having electrical contacts on it. A keyhole is, therefore, still necessary.

This invention in its various aspects is concerned to provide locking devices which ameliorate at least some of the disadvantages of the known systems and enable the provision of a practical and effective locking system.

This invention provides in one aspect an electronic padlock having a casing mounting a hasp movable between locked and unlocked positions, and containing a mechanism for retaining the hasp in its locked position, and a signal recognition circuit for identifying a predetermined signal pattern and actuating the mechanism in response thereto, the padlock having an inductor adapted to be inductively coupled to a key unit for receiving an alternating electrical signal therefrom and applying a signal to the signal recognition circuit, and the signal recognition circuit having reprogramming means which comprises an electronic store for storing a multibit lock code, whereby a new signal pattern can be programmed in the signal recognition circuit.

If the casing is a two-part casing the reprogramming means can be arranged such that it is made accessible when the casing is disassembled. Alternatively the padlock can be reprogrammed to accept a new code without opening the case, by transmitting through the inductive coupling the appropriate signal pattern. The new code sequence replaces the old code sequence in a non-volatile memory within the padlock. In either way the padlock can be reprogrammed to accept a new code relatively easily separately from the locking mechanism.

In another aspect the invention provides an electronic locking system, comprising a lock having an electronic store containing a multibit lock code and means for comparing the stored code with a received code to actuate a lock release mechanism in response thereto, and a programming unit for reprogramming the lock by entering a new lock code in the store, the programming unit being adapted to generate a new lock code with the use of a random or quasi-random number.

In a further aspect the invention provides an electrical lock comprising an inductor for being inductively coupled to a key unit for receiving an alternating electrical signal therefrom, a power circuit connected to the inductor to store and provide electrical power, a signal recognition circuit connected to the inductor for identifying a predetermined signal pattern received by the inductor, and a lock release mechanism actuated by the signal recognition circuit, in which the signal recognition circuit is constructed to provide a predetermined delay after receipt of one signal pattern from the inductor before it will process a subsequent signal pattern from the inductor, the said delay being of at least one second. By providing such a delay, the security of the lock is improved, as it becomes less susceptible to being released by a purely random input. The time taken to sequence through a useful number of possible codes can be made so long as to render the likelihood of the correct code being found accidentally utterly remote.

According to the invention there is also provided a padlock having a two-part casing, a hasp movably mounted relative to the casing between a locked position in which its free end is located within an aperture in the casing and an unlocked position, a mechanism within the casing for retaining the hasp in its locked position, and fastening means for securing the two casing parts together, in which the fastening means is accessible through the said aperture when the hasp is in only the unlocked position to enable the casing parts to be disassembled for access to the interior thereof. When locked, the padlock cannot be opened except by being totally destroyed.

In another aspect the invention provides an electronic padlock comprising a hasp movable between locked and unlocked positions, an inductor for being inductively coupled to a key unit for receiving an alternating electrical signal therefrom, a power circuit connected to

the inductor to store and provide electrical power, a signal recognition circuit connected to the inductor for identifying a predetermined signal pattern received by the inductor, and a lock release mechanism actuated by the signal recognition circuit to allow the hasp to move from its locked to its unlocked position, in which the lock release mechanism comprises an elongate member adapted to move into and out of engagement with the hasp to lock the hasp when the latter is in its locked position, and retaining members acting against detent means on the elongate member to retain the elongate member in its locking position, the retaining members acting symmetrically on opposed sides of the elongate member. The retaining members may be springs or bars which have to be moved in opposing directions away from the detents to release the elongate member. These springs or bars can be activated by electromagnetic coil means. To prevent false actuation by a powerful external magnet a shorting bridge preferably surrounds the solenoid area.

According to the invention there is also provided a keyholeless electronic locking system comprising a lock and an electronic key, the lock and key having inductive coupling means which are inductively coupled on presentation of the key to an appropriate location on the lock, the key comprising signal transmitting circuitry for transmitting coded unlocking information to the lock through the inductive coupling, and switch means for initiating operation of the signal transmitting circuitry, wherein the switch means is automatically actuated to activate or initiate operation of the signal transmitting circuitry upon presentation of the key into inductive coupling relation with the lock.

The switch means may preferably take the form of a reed switch which is automatically closed by a magnet element located on the lock.

Other features and advantages of a preferred embodiment of the invention will become apparent from the following description, given by way of example, with reference to the drawings, in which:–

Figure 1 is a sectional view through an electronic padlock;

Figure 2 is a side sectional view taken on the line II–II of Fig. 1;

Figure 3 is a block circuit diagram of the electronic circuitry in the padlock;

Figure 4 is a block circuit diagram of the electronic circuitry in the key unit;

Figure 5 is a block circuit diagram of the programming unit;

Figure 6 is a block diagram of a key unit of a second embodiment of the invention;

Figure 7 is a block diagram of the lock unit of the second embodiment;

Figure 8 is a perspective view of the programming unit of the second embodiment;

Figure 9 is a sectional view through the mechanical structure of the padlock of the second embodiment;

Figure 10 is a detail part-sectional view taken on the line A–A in Fig. 9; and

Figure 11 is an illustration of the automatic switch-on arrangement for the key unit of Fig. 6.

The first locking system illustrated in Fig. 1 to 5 comprises three principle components, namely a padlock (Figs. 1 to 3), a key unit (Fig. 4), and a programming unit (Fig. 5). These will be described in turn.

The padlock 10 has a general configuration much like any conventional padlock, in that it has a casing 12 and U-shaped hasp 14 which is movable between locked and unlocked positions. To this end the hasp may be pivotally mounted on the casing, but preferably, as shown, is longitudinally movable parallel to the arms of the U. The free end 16 of the hasp is received in an aperture 18 in the casing 12, and the retained end 20 also slides through an aperture 22 in the casing. The end 20 receives a bolt 24 the head of which is wider than the size of the aperture 22 to ensure that the hasp is retained. The free end 16 of the hasp has a transverse bore 26. When in the locked position the end portion 28 of an armature 30 of a solenoid 32 engages the bore 26 to lock the hasp in position. If a suitable pulse is applied to the solenoid winding the end portion 28 of the armature is withdrawn from the bore allowing the hasp to be released. A latching mechanism 34 is preferably provided which holds the armature clear of the hasp until the hasp is again pushed into the aperture 18. Thus the padlock can be locked without use of the key unit. The armature 32 is provided with a damping spring 36. When the hasp is unlocked, it can be slid outwards, under spring bias if desired, and when the free end 16 is clear of the casing 12, the hasp can be rotated about the longitudinal axis of the retained end 20.

The casing 12 is formed in two parts, namely an upper part 40 which mounts the hasp and houses the release mechanism as just described, and a lower part 42. The two parts fit together around the periphery of the casing to provide a reasonably well sealed overlapping join 44. The lower part houses the padlock electronics, not shown in Figs. 1 and 2. The casing or shell may be made for example of stainless steel, brass or aluminium except for a small area on the lower part 42 of the casing which contains a ferrite insert 46, thus enabling magnetic coupling through this region. The two casing parts are secured together by a bolt 50 which is held captive in a bore in a transverse plate 52 in the upper casing part 40 by means of a circlip 54. The threaded portion of the bolt 50 engages with a threaded bush 56 on the lower casing part

42 thereby drawing the two casing parts together. The head 58 of the bolt 50 is given a special shape and is arranged to be in line with the aperture 18 which receives the free end of the hasp 14. Thus when the hasp is free the bolt can be undone by inserting a special tool in the aperture 18. Access to the interior of the casing is thus possible. However, when the hasp is in the locked position the bolt 50 is totally inaccessible and the two casing parts cannot be separated.

The detailed physical construction of the components within the lower part 42 of the casing is not shown and for the most part is immaterial. An inductor winding is placed within the ferrite insert 46 to pick up signals radiated by the key unit of Fig. 4. The lower part of the casing houses circuitry which is described below with reference to Fig. 3 and which is connected to the inductor winding. The circuitry has an output terminated at the top edge of the lower part 42 which is connected to the solenoid 32 by means of appropriate contacts or connector members. The lower part 42 contains an integrated circuit chip having contacts which can be made accessible when the casing is opened and can be fitted into a standard multiway connector for reprogramming the circuitry as will be described below. These contacts are diagrammatically illustrated at 60 on Fig. 1 but may take a different form to that shown. When the electrical components are positioned in the lower casing part 42, the casing part is then filled with epoxy resin to seal it and inhibit access to the electronics.

In an alternative arrangement, not shown, the solenoid 32 is operative to latch the hasp by use of the intermediary of a rotating vane which rotates to locate into a recess in the hasp. This has the advantages that 'striction' and friction is easier to overcome, and that an inertial shock would have to be applied in a rotary form to have any chance of dislodging the vane from the hasp. This is virtually impossible with the padlock in position and locked, and makes the lock virtually immune to release without the key unit by physical manhandling.

The padlock electronics will now be described with reference to Fig. 3. Behind the ferrite window 46 there is the inductor winding 70 which can be inductively coupled to the inductor 114 constituting the output member of the key unit or key controller. Connected to the winding is a d.c. supply circuit 72 which rectifies and smoothes the output of the transformer 70 and provides some power storage in a capacitor. The padlock contains no battery. The d.c. supply circuit 72 provides voltages Vc for the electronic circuitry and Vp for the solenoid 32.

A frequency discriminator 74 is a.c. coupled by a capacitor 76 to the winding 70 and senses three signal conditions. The first is a signal at a first frequency f_1 which is used to power up the d.c. supply circuit 72. In response to this frequency the frequency discriminator 74 generates a reset pulse on a line 78. The second and third outputs 80 and 82 of the discriminator 74 are both responsive to a second input frequency f_2. This transmits data in binary form using pulse width modulation. The detected data values are applied to output 80 of the discriminator 74, and clock pulses associated with them are applied to output 82.

The circuit also includes a counter 84 having a count input 86 and a reset input 88, and a programmable read-only memory (PROM) 90 connected to be addressed by the counter. The PROM outputs the stored data code which is applied to a comparator 92 in the form of an exclusive-OR gate, the output of which is applied to a D-type flip-flop circuit 94. The PROM has a second output which is applied through a buffer amplifier 96 to operate the solenoid 32. A diode 98 is connected across the solenoid to permit any reverse ringing current to flow. Finally the Q output of the flip-flop 94 is connected to the reset input 88 of the counter 84 through an OR gate 100. It is the PROM 90 that carries the contacts 60.

The operation of the circuit of Fig. 3 is thus as follows. Initially the key unit (of Fig. 4) provides a signal of frequency f_1. This is used to charge up the d.c. power supply 72. When sufficient power is accumulated for operation of the circuit, a reset pulse will be provided on line 78 which passes through the OR gate 100 to reset the counter 84, and also resets the D-type flip-flop 94. As the counter 84 is reset, the zero location of the PROM 90 will be addressed. The PROM contains, in a manner to be described, the *n* bits of the code which are required to open the lock, these bits being held in the first *n* addressable locations in the PROM. Thus at this point in time the first bit of the data code held in the PROM, termed DATA(LOCK), is applied to the comparator 92.

After the frequency f_1 has been transmitted for a predetermined duration, sufficient to charge up the d.c. power supply, the key unit shifts to frequency f_2 and starts transmitting the key code. The data bits are transmitted by pulse width modulation, and when each bit is identified by the discriminator 74 and applied to line 80 as DATA(KEY), a clock pulse is transmitted on line 82. Thus the first detected bit is applied to gate 92 where it will be compared with the corresponding data bit held in the PROM 90. As the comparator 92 is an exclusive-OR gate, the identity of its two inputs produces a zero output which is applied to the flip-flop 94. The flip-flop 94 is clocked on the leading edge of the clock pulse on line 82, and in this case the Q output of the flip-flop will also be zero. The trailing edge

of the clock pulse now counts up the address counter 84 so that the next stored bit is applied to the comparator 92 to await the next detected bit. This cycle then continues, so long as the stored and detected bits agree, through all the *n* bits of the stored data code. After the *n* th bit the next up count applied to the counter will address a location in the PROM which causes an output to be applied to the power amplifier 96 to actuate the solenoid 32, which receives power from the d.c. supply 72.

If, at any point in the sequence, the detected and stored bits differ, the inputs to the exclusive-OR gate 92 will not match. In this case a one output will be applied to the flip-flop 94 and the Q output will also be a one, thus constituting an ERROR signal. This is applied through gate 100 to the reset input 88 of the counter 84. This readdresses the PROM location so that it can never reach location $n+1$ which is necessary to actuate the solenoid 32. Furthermore, in order to attempt again to open the lock it is necessary to wait for a predetermined period of, say, 1 second, though a delay of half a second may be sufficient. This means that the time required to cycle through even a small fraction of the possible *n*-digit codes is very considerable, particularly if, for example, *n* is of the order of 64. The delay may be provided by an internal clock in the PROM.

A typical time duration for the first frequency transmission would be about a half second, and the time for transmission of a 64 bit code would also be of the order of a half second, so that the total operation time to unlock the padlock is only one second, which is quicker than for a manual key-operated lock. These time periods can, of course, be varied.

The key unit 110 is shown in Fig. 4. This is a battery powered unit, and has an output winding 114 which inductively couples to the winding 70 of the padlock circuit. The unit has a push-button 116 which when depressed connects the battery 112 to the rest of the circuit, and this initiates a transmission sequence. A lower voltage is required for some of the circuitry and is supplied by a voltage regulator 118.

A state sequence counter 120 receives the output of an R–C oscillator 122 and initiates the various stages of operation. A PROM 124, similar to the PROM 90 of the padlock, is connected to be addressed by a latch circuit 126 which is incremented by each code data output bit from the PROM 124. A voltage controlled oscillator/mixer 128 provides an output through a power amplifier 130 to the winding 114.

Upon depression of the button 116, the PROM address is reset to zero, and the frequency f_1 is transmitted to the winding 114. After a predetermined period, set in the sequence counter 120, the frequency is changed to f_2, and the code data in the PROM 124 is used to modulate the data by pulse width modulation.

Thus, in use, all that is necessary to open the padlock is to place the key unit with its transformer adjacent the ferrite window 46 of the padlock, and press the button 116.

A suitable oscillator frequency would be in the region of 20 kHz, with auto-zero insertion to ensure flux transitions on all data bits transmitted, regardless of logic state. Thus power "pumping" is maintained during data transmission even if a string of zeros or ones is being transmitted.

It is envisaged that in normal use of-the system there will be a plurality of padlocks which can be unlocked by one or more key units. The same code will be used in all the units of the system. Where a 64 bit code is used, the first 20 bits may be set by the system manufacturer as being a code identifying that particular customer. The remaining 44 bits are generated by the programming unit on a random or quasi-random basis and will thus not normally be known to any human being. These 44 bits can be altered by reprogramming the key units and padlocks in the system.

The programming unit 140 is based on a standard programming unit and is thus not described in detail. As shown in Fig. 5, it comprises a micro-processor 142 provided with a keypad input 144 and a display 146, and connected to a master multi-way socket 148 and one or more ganged slave sockets 150. Each of these sockets will receive the contacts 60 connected to the PROM 90 in the padlock or the PROM 124 in the key unit. The required voltages are generated in a power supply 152 under micro-processor control.

When it is desired to reprogram the system to use a new data code, for example in the event of the loss of a key unit, one of the PROMs is removed from the key unit or lock and is placed in the master socket on the programming unit. The programming unit generates a 44 bit random number which it combines with the previous code to provide a new 44 bit code. This combination with the previous code further reduces the already negligible chance of regenerating the same code sequence twice in a row. This new code is then used to replace the code in the master PROM and at the same time to enter the same code in the other PROMs which are plugged into the slave sockets 150. When the reprogramming operation is completed, the PROMs are returned to the key units and locks, and when the programming unit is switched off the new code is erased.

An alternative locking system constituting a second embodiment of the invention is shown in Figs. 6 to 11, and the padlock electronics

will be described with reference to Figs. 6 and 7. Much of the system is similar to the first example and will not be described again in detail, and where appropriate the same reference numerals are used. The lock circuitry is shown in Fig. 7. Within the ferrite window 46 there is the inductor winding 70 which can be inductively coupled to the inductor 114 constituting the output coil of the key unit (or the programmer, as will be described below). Connected to the winding 70 is a d.c. supply circuit 72 which rectifies and smoothes the output of the winding 70 and provides power storage in a capacitor. The padlock contains no battery. The d.c. supply circuit 72 provides voltages V_c for the electrode circuitry and V_p for the solenoid 32.

A frequency demodulator 74 is a.c. coupled by a capacitor 76 to the winding 70 and senses three conditions. The first is no signal being received. In this state, assuming residual power in the storage capacitor within the power supply, the signal-detected line 78 outputs a logic signal to a microprocessor 153 conveying this status. The second condition is the reception of a frequency f_1 which is used to power up the d.c. supply circuit 72. In response to this frequency the demodulator 74 generates a "signal detected" logic output on line 78, which is connected to one of the inputs of the microprocessor 153.

A second logic signal output 80 of the demodulator 74 is responsive both to the frequency f_1 which represents one logic level and to a frequency f_2 which represents a second logic level. Data is thus received in binary format i.e. toggling between f_1 and f_2. This form of information transmission is generally known as frequency shift keying (FSK). The resulting binary data stream is applied to one of the inputs of the microprocessor 153.

After the frequency f_1 has been transmitted for a predetermined time, sufficient to charge up the d.c. power supply 72 to its terminal value, the incoming signal begins toggling between f_1 and f_2 in accordance with data representing the key code sequences. The exact format of these sequences is not critical to the invention.

The microprocessor 153 processes this data sequence which was transmitted to it from the key unit of Fig. 6 and, when the correct data or code sequence has been received, the microprocessor operates a release mechanism via a switching circuit 154. The correct code sequence against which the incoming data is compared is stored in a non-volatile random access memory (RAM) 155 within the padlock.

The key unit in the alternative arrangement is shown in Fig. 6. This is a battery powered unit and has an output winding 114 which inductively couples to the winding 70 of the padlock circuit. The key unit has a reed switch 157 which, when closed, connects the battery 112 to the rest of the circuit, and this initiates a transmission sequence. The regulated voltages required by the key electronics are supplied via a power supply regulator 118.

The reed switch 157 on the key unit is closed automatically when the key unit is brought into close proximity with the lock, by magnet means on the lock. As shown on Fig. 11, the ferrite window 46 on the lock is provided with two small magnets 173, one to either side of the coupling coil 114. When the key is brought close enough for the coils 70 and 114 to couple inductively, one of the magnets 173 will close the reed switch 157. Two magnets are provided so that the key can be oriented in either of two 180° diametrically-opposed positions. In this way power switch-on and/or transmission sequence initiation for the key unit can be effected automatically.

Reverting to Fig. 6, the key unit contains a non-volatile RAM circuit 156 in the form of a plug-in module, and a microprocessor 174 which outputs a control sequence to a modulator 176 in accordance with the contents of the memory 156, as previously programmed by the programming unit described below. The modulator output is applied through a coil driver circuit 178 to the coil 114.

To change the reference code sequence stored in the non-volatile memory 155 in the padlock, a special key, called here a programming unit, transmits both the old key code sequence (a) and the new key code sequence (c) together with a command code (b) to the padlock. The microprocessor 153 in the padlock compares the incoming code sequence (a) with the stored code sequency already in the RAM 155 and thus recognises the programming unit as having valid access. It then recognises code (b) which tells the microprocessor to be ready to accept a new key code sequence (c) before opening. The programming unit next transmits the new code sequence (c) which is to be stored by the padlock in place of the existing code sequence (a). If the padlock microprocessor had not recognised the three code sequences (a), (b) and (c), it would have taken no action. Otherwise it activates its hasp release mechanism to indicate update of its stored code sequence.

By means of the plug-in module 156, standard keys are changed to transmit only the new code sequence (c). The plug in module 156 contains this code sequence in a non-volatile memory, which is used to replace the module originally plugged in to the key. These code modules are programmed with the relevant code sequences by the programming unit. The programming unit of Fig. 8 is an alternative arrangement appropriate to the key and lock realisation of Figs. 6 and 7. The programming unit is based again on standard electronic circuitry and is not described in

detail. It comprises a microprocessor, push button keys 158 and lamps 159, with a master socket 160 for a master key code module and one or more slave sockets 161. When it is desired to reprogramme a padlock and key with a new code, the sequence by way of illustration can be as follows with reference to Fig. 8.

The operator inserts the current "master module" into the programmer's master socket 160 and a blank, or no longer valid, code module (which is to be re-programmed) into the "program" socket 161. The current master just plugged in must contain the current code of those padlocks which are now to be re-programmed with a new code. No one can illegally reprogram a padlock unless he has access to the current code inside the padlock. The operator first presses the "new code" button to generate a new random code inside the programmer for example in the same manner as in the embodiment of Figs. 1 to 3. When the processor has generated this new code the lamp above the "new code" button lights up. Next the "programme master" switch is pressed. When the processor has reprogrammed the "master module" with a new code, the indictator above the "programme master" switch lights up. It should be noted that the master module still contains the previous code sequence as well as the new one, as the padlocks which are to be reprogrammed can only respond to the previous code.

To change the code in a padlock it is placed in a special slot 162 located on the programmer. The operator then presses the "program padlock" button and holds it down. The programmer than sends three code sequences to the padlock as described above, two of which sequences are held in the master module. The first of these three codes is the original code to which the padlock will respond. Immediately after recognising its valid code the padlock receives a second standard non-varying code sequence which tells the padlock not to spring open yet, but to get ready to accept a new code and modify its memory to respond only to this new code. The third and new code sequence is then set to the padlock. This code contains an extra sequence of check digits so that the padlock is sure it has received the code correctly. It then knows it is safe to eradicate the old code from its memory and replace it with the new. The padlock will then spring open informing the operator in this way that all is now complete and he can now release the "reprogram padlock" button.

While the button was pressed the programmer automatically repeated the above process until the padlock sprung open or the operator released the button. This caters for the rare occasion when the padlock might fail to reprogram correctly the first time through. To re-program one of the "code modules" that is used with the keys in the field, the operator, having inserted a module into the program socket 161, pushes the "duplicate" button. The programmer now reads the new code from the master module into the module in the program socket. When programmed, the light above the button lights up. The module can now be sent to a key holder in the field to allow him to open a reprogrammed padlock when it arrives locked at his location.

There is the possibility that the operator may want to re-check code modules against the master module. To do this both modules are plugged into their respective sockets and the "verify" button depressed. If the current codes match, the lamp above the button lights up. If re-programming the master module or code module fails because the modules are damaged for any reason, or if the "Verify" test is negative, the FAIL light comes on. This light is not used when re-programming padlocks as the hasps will spring open if all goes well, but stay frustratingly shut on failure.

In this second embodiment of the invention, it is not necessary to be able to open the padlock casing. One realisation of the design of such a padlock is shown in Figs. 9 and 10. The operation of such a padlock is described first as to how it locks shut and then how it snaps open.

To close the padlock the hasp 163 is pushed down into the padlock body 180. Two springs 166 and 167 are thereby compressed, spring 167 being directly compressed by the captive end of the hasp, and spring 166 being compressed by the contact point 165 of a lever 164 pivoted about a pivot point 182. The lever 164 also carries a lug 168 which engages a rod 169. The rod 169 is slidable in a transverse bore 184 which is intersected by the free end of the hasp 163. When closed, a recess 170 on the hasp is engaged by the end of rod 169 thereby locking the hasp closed. The rod 169 is moved into this position because insertion of the hasp into the body rotates lever 164 counter-clockwise as seen in Fig. 9, and lug 168 then pushes rod 169 to the left to lock the end of the rod in the recess 170, thereby retaining the hasp 163. The rod 169 has a narrowed section 186 to receive the lug 168.

To retain the rod 169 in this position to lock the hasp, two side springs 171 are provided. The side springs are of a magnetically attractive material, such as iron, and drop into two indents 172 in the sides of rod 169. This is shown also in the detail of Fig. 10. The hasp cannot now be withdrawn. Spring 167, which was compressed on closing the lock, pushes the hasp away from point 165 of mechanism 164 to set the lock in a state ready for its later electronic opening.

To open the padlock, two coils 32 are

energised by circuit 154 in Fig. 7. These magnetically pull the two springs 171 out of the indents 172, releasing rod 169 which is moved to the right by lug 168 of level 164. Lever 164 moves under the influences of compressed spring 166 about pivot point 182. Once rod 169 is moved to the right out of recess 170 in hasp 163, spring 167, which was also compressed when the lock was closed, pushes the hasp upwards to reopen the lock.

It will be seen that the hasp release mechanism has a symmetrical structure, and the springs 171 have to be moved in opposing directions out of the recesses 172 to release the rod 169. Thus the lock resists opening by mechanical shock. To prevent false actuation by a powerful external magnet a shorting bridge 179 surrounds the solenoid area.

The bottom face of the body 180 is closed by a plate 188 secured to the body 180 by a swaged seal 190. Alternatively the lock casing could be in two parts which are held together by an irreversible latching machanism. The electronic circuit elements are housed in the cavity 192 thereby formed in the body 180.

It will be seen that the systems described above in Figs. 1 to 5 and 6 to 100 respectively have a number of most advantageous features which make them extremely effective and easy to use and provide good security against unauthorised access. For instance:–

1. If a key is stolen, the padlocks do not have to be replaced, merely reprogrammed.
2. All key information is located in the code modules which are small and convenient for storage in a safe.
3. No code knowledge is available to users of the system.
4. No batteries which can discharge or corrode are used in the padlock.

CLAIMS

1. An electronic padlock having a casing mounting a hasp movable between locked and unlocked positions, and containing a mechanism for retaining the hasp in its locked position, and a signal recognition circuit for identifying a predetermined signal pattern and actuating the mechanism in response thereto, the padlock having an inductor adapted to be inductively coupled to a key unit for receiving an alternating electrical signal therefrom and applying a signal to the signal recognition circuit, and the signal recognition circit having reprogramming means which comprises an electronic store for storing a multibit lock code, whereby a new signal pattern can be programmed in the signal recognition circuit.

2. A padlock according to claim 1, in which the reprogramming means comprises means coupled to the inductor for recognising a reprogramming code and for altering the stored lock code in response thereto.

3. A padlock according to claim 1 or 2, further provided with a programming unit for generating a new lock code with the use of a random or quasi-random number.

4. A padlock according to claim 1, 2 or 3, in which the casing is a two-part casing, and reprogramming means is arranged such as to be made accessible when the casing is disassembled.

5. A padlock accordng to claim 4, including fastening means for securing the two casing parts together, in which the fastening means is accessible through an aperture which is closed by the hasp when the latter is in its locked position whereby the casing can be disassembled for access to the interior thereof only when the hasp is in the unlocked position.

6. An electronic locking system, comprising a lock having an electronic store containing a multibit lock code and means for comparing the stored code with a received code to actuate a lock release mechanism in response thereto, and a programming unit for reprogramming the lock by entering a new lock code in the store, the programming unit being adapted to generate a new lock code with the use of a random or quasi-random number.

7. Apparatus according to claim 3 or 6, in which the programming unit generates a new lock code by combining a previous lock code with the random or quasi-random number.

8. An electronic lock comprising an inductor for being inductively coupled to a key unit for receiving an alternating electrical signal therefrom, a power circuit connected to the inductor to store and provide electrical power, a signal recognition circuit connected to the inductor for identifying a predetermined signal pattern received by the inductor, and a lock release mechanism actuated by the signal recognition circuit, in which the signal recognition circuit is constructed to provide a predetermined delay after receipt on one signal pattern from the inductor before it will process a subsequent signal pattern from the inductor, the said delay being of at least half a second, and preferably one second.

9. An electronic padlock comprising a hasp movable between locked and unlocked positions, an inductor for being inductively coupled to a key unit for receiving an alternating electrical signal therefrom, a power circuit connected to the inductor to store and provide electrical power, a signal recognition circuit connected to the inductor for identifying a predetermined signal pattern received by the inductor, and a lock release mechanism actuated by the signal recognition circuit to allow the hasp to move from its locked to its unlocked position, in which the lock release mechanism comprises an elongate member adapted to move into and out of engagement with the hasp to lock the hasp when the latter is in its locked position, and retaining mem-

bers acting against detent means on the elongate member to retain the elongate member in its locking position, the retaining members acting symmetrically on opposed sides of the elongate member.

10. A padlock according to claim 9, in which the lock release mechanism includes solenoid means responsive to the signal recognition circuit to move the retaining members out of engagement with the elongate member.

11. A padlock according to claim 9 or 10, in which the elongate member is resiliently biased towards the unlocked position, and including lever means actuated upon movement of the hasp into the locked position to move the elongate member into its locking position against the resilient bias in which position it is retained by the retaining members.

12. A keyhole-less electronic locking system comprising a lock and an electronic key, the lock and key having inductive coupling means which are inductively coupled on presentation of the key to an appropriate location on the lock, the key comprising signal transmitting circuitry for transmitting coded unlocking information to the lock through the inductive coupling, and switch means for initiating operation of the signal transmitting circuitry, wherein the switch means is automatically actuated to activate or initiate operation of the signal transmitting circuitry upon presentation of the key into inductive coupling relation with the lock.

13. A system according to claim 12, in which the switch means comprises a magnetically-operable switch which is automatically closed by a magnet element located on the lock.

14. A system according to claim 12 or 13, in which the signal transmitting circuitry is adapted to transmit a power transmission followed by a multibit lock code transmission, and closure of the switch means initiates the power transmission.

15. A system according to claim 14, in which the key is provided with a manually-operable switch which when actuated causes the lock code transmission to take place after the power transmission.

16. A padlock having a two-part casing, a hasp movably mounted relative to the casing between a locked position in which its free end is located within an aperture in the casing and an unlocked position, a mechanism within the casing for retaining the hasp in its locked position, and fastening means for securing the two casing parts together, in which the fastening means is accessible through the said aperture when the hasp is in only the unlocked position to enable the casing parts to be disassembled for access to the interior thereof.

17. A keyhole-less electronic locking system substantially as herein described with reference to Figs. 1 to 5 of the drawings.

18. A keyhole-less electronic locking system substantially as herein described with reference to Figs. 6 to 11 of the drawings.

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